

Radiolarite sources from the Bakony mountains: new research

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New geological data on the Transdanubian radiolarites and a revision of the so called Szentgál-complex has brought a new archaeological picture of the Bakony mountains. Earlier radiolarite subgroups such as Szentgál-type, Hárskút-type or Úrkút-Eplény-type have no further relevance, because colour variation cannot be used as an indication of the exact location of the different chert outcrops. All possible colour variations, from brick-red to dark brown and varying yellowish, can be found in all parts of the Bakony mountains. Independent CRF-examinations resulted in similar observations. Such radiolarites can be found throughout the Bakony mountain range with uniform variation across the massif. Technological examination of different chopped tools from the surrounding archaeological settlements of Szentgál has provided fresh data: the settlements round Szentgál were not directly connected to the mines and to tool production. The presence of flakes, reduced cores, tablets and large volumes of waste indicate that these were not workshops preparing the mined raw material, but rather sites of regular tool production.

KEY-WORDS: chert, radiolarite, Transdanubian radiolarite, Bakony mountains, CRF-examination, Szentgál-komplex

INTRODUCTION

The diversity of raw materials in the chipped stone industry in the Transdanubian region of Hungary is not that significant. The so-called Transdanubian radiolarite dominates the archaeological lithic assemblages, mostly in conjunction with different grey flint types from Tevel and other areas of the Bakony mountains. Obsidian is seldom found in the lithic collection, as retouched tools or as *supports*. This manner of lithic variation was typical of the Neolithic period and changed only in the early Copper Age/Chalcolithic when bifacial techniques appeared in the region and new communities started to exploit 'local' raw material outcrops (different limnosilicite and opal sources) probably in Burgenland.

Flint was always a very important raw material in chipped stone production. Good knapping quality, conchoidal fracture, the hardness and rigidity of this rock material

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ensured a very good base for tool production. Comparing different materials from the earliest periods, we find extensive variation of the raw materials of different origin and quality (flint, radiolarite, horn flint, opal, limnosilicite, etc., Biró 2010: 198–199). This can be divided into five larger groups as proposed by Antonín Přichystal: siliceous sediments (silicides), minerals of SiO₂, natural glasses, classic silica sediments and other rocks (Přichystal 2010: 178).

The main difference between silicides and silicon dioxide minerals is that silicides contain microfossil remains. These can be radiolarians, foraminifers, echinodermatas or other siliceous sponges (Brandl 2014: 44–45). The different obsidians and horn flints are natural glasses, while the classic silica sediments are built of quartz and flint debris (Přichystal 2010: 178–179). Silicon dioxide constitutes 80–90% of the inner cluster of radiolarian chert and the other main component is calcite. From a petrographic point of view, radiolarians can therefore be preserved in different ways, the selection which types of radiolarian skeletons remain and which are deformed or completely disintegrated occurring during the crystallization process. Even so, the filled out shape can be preserved and is easily recognised under a microscope (Mateciucová 2008: 48). The colour varies from black to dark brown and different shades of grey; from blue to reddish brown, green, brown or brick-red, white and yellow (Brandl *et al.* 2013: 147). The geological processes responsible for such wide colour variations are not always immediately clear. The red colour is generated primarily by hematite, iron oxide or hydroxide, while the darker colours are created by magnesium chloride or iron (III) chloride. Different iron chlorides are responsible for the green colour (Cheben and Cheben 2010: 26; Hauptmann 1981: 9).

RADIOLARIAN CHERT FROM THE BAKONY MOUNTAINS

Radiolarian chert of different colour is the most representative, beside flint, among the archaeological finds from Transdanubia. Moreover, the Transdanubian variants of chert from Sümeg, Gerecse and Bakony (Biró *et al.* 2009: 26) are the most widespread form of raw material from Hungary in the Neolithic period. Radiolarian chert is an organogenic flint stone occurring in limestone layers from the Mesozoic period (Konda 1986: 165–169). Older cherts are known from the earlier Triassic Period, from a geological formation called the Vászoly and Bruchenstein platform (Budai and Csillag 1998: 19).

The evolution of radiolarian chert in the Bakony mountains started approximately 165 million years ago, already in the middle Jurassic period, in the bench of the Bath level (Dobosi 1978: 12; Dosztály 1998: 277). The main content are the different pure radiolarians: the triptylea and the polycystina (Brandl 2014: 44). A traditional archaeological study classified the radiolarites as Szentgál-type (red), Úrkút-Eplény-type

(mustard yellow) and Hárskút-type (brown) based on the colour of the rocks (Biró 2008: 22). This classification also related the radiolarite types to distinct geological formations, but the geological structure of Bakony Mountains does not support this suggestion. The geomorphology of the mountain range is a unified stratum articulated with basins and slopes. In the Jurassic era, at the Bath and Callovian levels, a large volume of radiolarian was deposited on the limestone in different thicknesses owing to surface variation. Because of this the silicic acid and carbonate content in the radiolarian cherts may vary despite the geologically uniform structure of the mountains of Transdanubia between the Gerecse mountains and Zala Basin (Vörös and Galács 1998: 76–77). Therefore, a single geological source may yield macroscopically different radiolarian chert, while morphologically similar chert can be found at different locations. Katalin T. Biró recognized this (Biró 1995: 405), but even so, a reddish hue remained the main discriminant of the Szentgál-type in their classification.

The exploitation of various types of radiolarian chert has long been the subject of archaeological research, the main focus being the study of long-range social and trading routes. To support these ideas, different scientific investigations have been applied to separate the types and their sources with a focus on the internal structure of radiolarian chert. The first attempts at these analyses were sporadic and destructive: OES in 1981 (Kozłowski *et al.* 1981), WS, OER, IR, XRD and NAA in 1986 (Biró and Pálosi 1981), NAA in 1991 (Biró and Dobosi 1991; Varga 1991) and different measuring sequences with PIGE-PIXE in 2002 (Biró *et al.* 2002). Within the frame of the Tét-Project a smaller examination with the non-destructive PGAA-method was accomplished on different radiolarian chert samples from the Transdanubian region (Biró *et al.* 2009). This method was successfully applied in other projects on different siliceous rocks (Kasztovszky *et al.* 2009: 37). The main goal behind these investigations was to differentiate the raw materials and connect them to specific geological outcrops. Of prime importance were analyses of trace element distribution. Small quantities and high variability of the raw material available for study identified the origin of the rocks down to the mountains: Gerecse, Mecsek and Bakony, but without differentiating between sources within these mountains. It was also shown that more than one type of radiolarian chert could originate from one geological site and different locations can yield similar samples, too. Examination of geological samples of different chert types from Szentgál, Úrkút-Eplény and Hárskút gave the same UCC (Upper Continental Crust) numbers. Geological samples from the Gerecse and Bakony mountains had nearly the same analytical curve. Moreover, archaeological samples from the excavation of Vörs, identified as cherts from Gerecse, had characteristics similar to the geological samples from the Bakony Mountain – the analytical curve was in full correlation (Biró *et al.* 2009: 38–39). These facts stand in confirmation of the theory that radiolarian cherts from the Jurassic Period are almost identical throughout Transdanubia, from Gerecse Mountain to Zala Basin, making their separation a challenge.

RADIOLARIAN CHERT FROM SZENTGÁL AND THE MINE AT TŰZKÖVESHEGY

The area of the Szentgál-Tűzköveshegy mine was known as a prehistoric site even in the early 20th century. In the 1980s, geological investigations mapped the different radiolarian chert deposits/outcrops. The first archaeological excavations were carried out from 1983 to 1985. Five mining pits and several heaps of radiolarite debris were registered on a wide plateau at the foot of the Tűzköves hill (Biró 1995: 402). There were no distinctive finds and the typological classification of the knapped lithics yielded no information for relative chronology. The radiocarbon charcoal sample from trench V yielded a date of 685±120 BP, referring to the medieval period (Biró and Regenye 1991: 341)¹. Each mining pit was of a different shape, which may indicate that they were dug in different periods employing different mining methods. The largest mining pit (Object 4) was oblong, almost 3 m at the deepest point and cutting across the radiolarian chert layers. The other pits were shallower (Biró 1995: 407). The main difficulty with the archaeological interpretation of the finds is that chert extraction continued into late medieval times and even the early 20th century.

New material and results

Four geological samples (L86/147–150) were recorded in the Lithotheca (Biró and Dobosi 1991: 47–48). The red types (L86/147 and 150) are described as local materials, the brown and the yellow ones (L86/148–149) as transported by chert miners from geological sources located elsewhere. New geological examinations concentrated on the whole hill and not only on the wide plateau and the vicinity of the modern quarry (Fig. 1).

On the plateau in front of the hill no useable/knapped radiolarian chert was found, most likely due to intensive mining activity in the 20th century. However, at the top of the hill and on the steep slopes a huge amount of debris, fragmented chert platforms and in some cases heaps of mining debris (flakes, bigger fragmented blocks, etc) can be found, occasionally accompanied by late medieval pottery fragments. The thicker chert beds can be traced easily along the whole hillside, where some layers are nearly 30 cm thick. Their colours are brown, red and brick-red, and in some cases, small black veins are visible in the texture of the rock.

CHERTS FROM HÁRSKÚT AND THE MINE OF ÉDESVÍZMAJOR

The raw material sources can be found in a Mesozoic limestone bed in the vicinity of Hárskút, between Gyenespuszta and Némettanya. The Jurassic radiolarian chert in

¹ Two different and independent laboratories obtained the same results (Biró and Regenye 2001: 95).

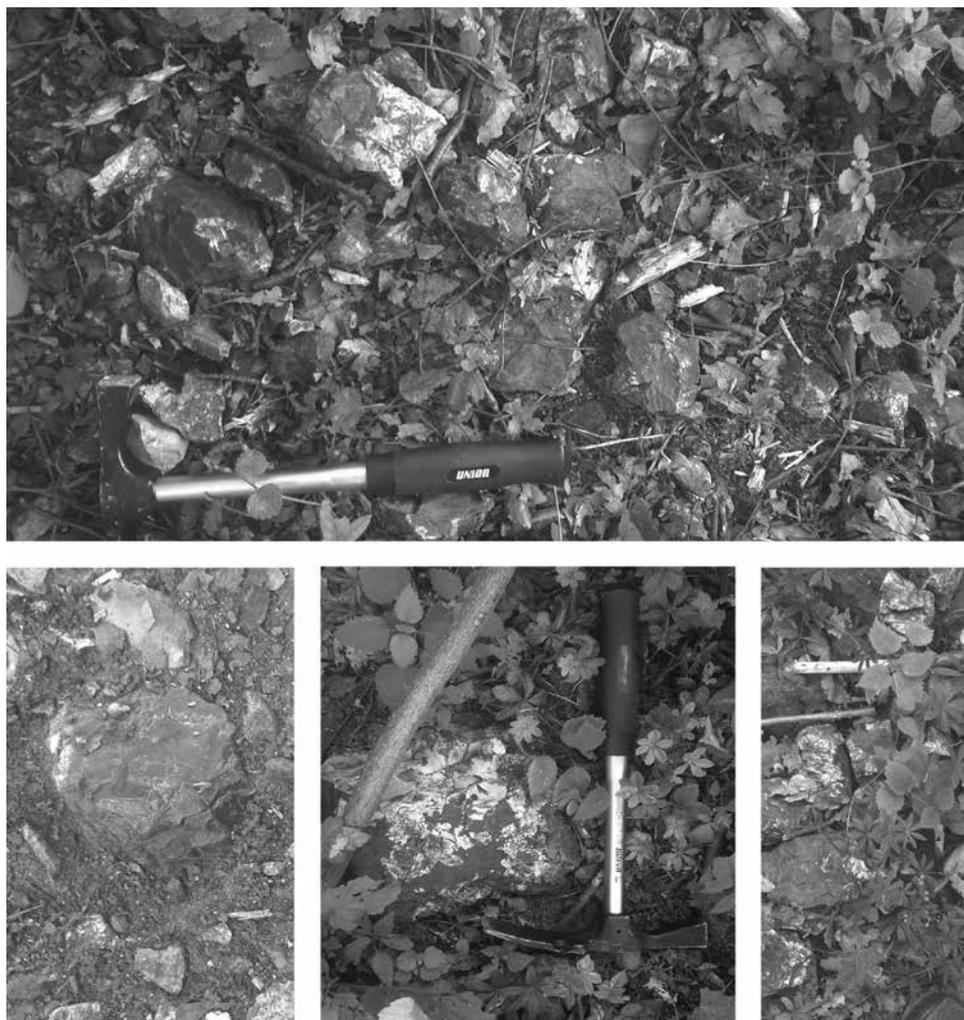


Fig. 1. Fragmented chert platforms in Szentgál-Tűzköves. Photo by the author

this area is mostly red, covering the whole area and can easily be mined. The first prehistoric mine was found during geological testing of the region by József Konda in 1970, the survey focused on localizing different chert layers. Some remains of mining activities were documented in the mining pits, approximately 180 cm below the surface: different mining tools, antlers, stone pebbles and mining debris (Bácskay 1982: 11; 1995a: 408).

New evidence from the collected raw materials

The Lithotheca contains five different geological samples (two pieces from Édesvíz-forrás, two pieces from Gyenespuszta and one piece from the vicinity of the Közöskút). The documented colours alternate between dark brown and red spotted, but the violet-coloured variation is also known (L86/088, Biró and Dobosi 1991: 32, 114). In Biró's traditional grouping only the dark brown chert pieces originate from Hárskút.

The new research in this geological formation concentrated on three larger areas: the smaller hummock between Gyenespuszta and Németpuszta (known also under the name of Édesvíz-forrás), a small hill called Rendkő (mostly its western slopes) in the western part of this area, and another hill called Borostyán-hegy in the southern part of Hárskút.

Hárskút – Gyenespuszta/Édesvíz-forrás (Némettanya) (Fig. 2)

In the vicinity of the known geological point, long strips of cracked platforms, debris and larger fragmented blocks can be detected on the steep slope. Thicker, fragmented and colourful radiolarian chert beds can be found in areas that are deeply rain-washed and on the eroded hillside. The chert deposits can be followed continuously along the northern and eastern sides of the hill. The average thickness of the chert layers is between 5 and 15 cm, but in some cases, much bigger blocks can be documented, 25–30 cm in size. There is a wide range of colours, alternating from the red and deep brown up to yellow and mustard yellow. Two main types of the reddish chert can be distinguished: one with an enhanced red colour which is very similar to the so-called Szentgál-type and the other one of light red colour with mottled dark veins. The dark brown pieces have a very clear and fine internal structure and their matrix is very similar to the Szentgál cherts. Beside these, a very unique chert type was found, until now unknown, changing colour from red to mustard yellow and usually spotted or striped with pale lines.

Hárskút – Rendkő and its vicinity

Colourful radiolarian chert beds can be found on the internal side of the wide hilltop plateau. Fragments of larger concentrations of nodules are present beside the eroded chert layers. The colour variants range from light red to dark brown. In some cases, mustard yellow and red-spotted yellow chert types can also be located.

Hárskút – Borostyán hill (Fig. 3)

A huge number of chert beds can be found around the settlement situated along the old and periodic anabranch of the Aranyos River, which cut deeply into the northern slope of the Borostyán hill along the steep and eroded slope of the hill. This hill is part of the Jurassic limestone massif. Larger nodules, varying in color from red to

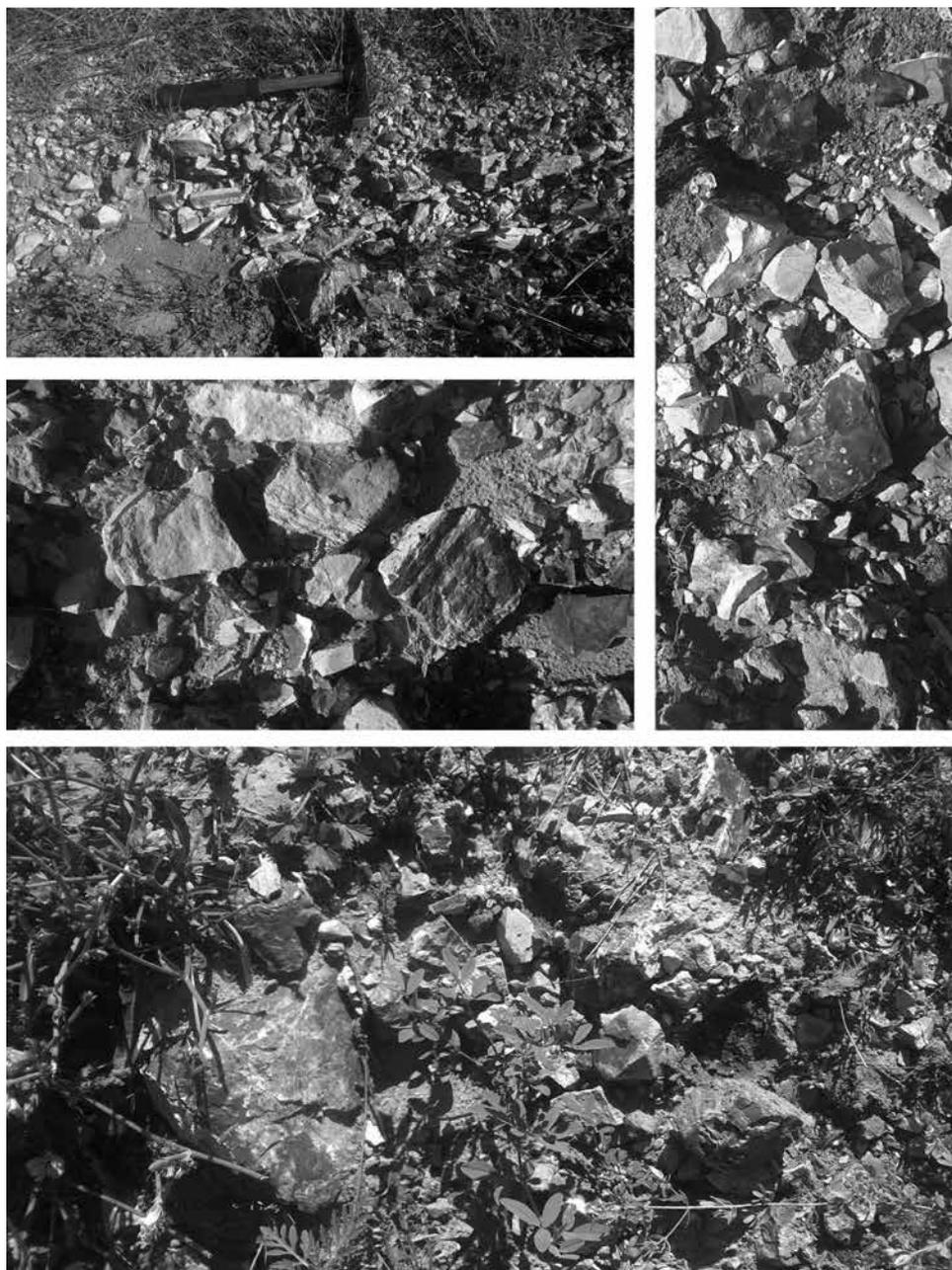


Fig. 2. Cracked chert platforms, debris and bigger blocks in Hárskút-Gyenespuszta/Édesvízmajor.
Photo by the author



Fig. 3. Eroded slope with chert beds in Hárskút-Borostyán Hill. Photo by the author

deep brown, can also be seen beside the fragmented chert blocks and bigger deep brown nodules and brick-red radiolarite platforms and blocks have also been documented next to the striped red chert types.

RADIOLARITES IN ÚRKÚT AND IN EPLÉNY AND THE QUESTION OF THE LÓKÚT-TYPE CHERTS

No evidence for mining activity or archaeological finds is known from this area. Yellowish cherts have been recorded in this area. The Lithotheca Collection has three important geological samples registered from the Csárda-hegy hill (L86/171 and

L89/038–039, Bíró and Dobosi 1991: 53, 141), all of which date from the Jurassic period. Their colours alternate between yellow and yellowish brown with white thin veins in the matrix. The area at present is under geological protection and no further collection or examination is possible. There is no evidence for comparative material from the area of Eplény. Geological maps show the Jurassic limestone bed formations mostly in the Lókút area and not in the vicinity of Eplény. Radiolarite chert deposits are found in this deep valley only on the border of Eplény. In the Lithotheca Collection these types were catalogued as chert from Lókút-Hosszúárok (L86/121–123, Bíró and Dobosi 1991: 41). In geological research, this valley is eponymous for radiolarian chert formations in Jurassic limestone (Dosztály 1998: 273–274). The most concentrated areas are in the awash valley of the so-called Gyökeres-völgy and in the northern eroded slopes of Mohos-kő hill.

Newly collected radiolarites from Lókút

Deeply cut in the valley surrounded by the northern face of Mohos-kő hill is the southern part of the settlement of Lókút. Radiolarian chert formations are easily traced throughout the rift valley owing to washed and eroded surfaces (Fig. 4). Mostly



Fig. 4. Chert formations in the Lókút-Mohos valley. Photo by the author

rectangular chert blocks can be found in colourful variety. Red, yellow, reddish-yellow, brick-red and brown types can be observed. The red types can be further subcategorised into two assortments: a homogenous type with shiny surface (the same as the so-called Szentgál-type) and a deeper red-coloured chert block formation with dark veins in the internal structure. The mustard-yellow type is also characteristic of the valley and has been registered already in different areas (for example, in Szentgál and in Hárskút). The internal structure of this yellowish chert is very homogeneous and sometimes with faint flecked or darker veins.

RADIOLARITE FROM SÜMEG

The colour of the raw material in this area is mostly grey, but reddish and pink varieties are present. The chert blocks are of high quality. Blocks are 10–15 cm wide mostly in the western part of the mine. As such, it is easy to locate and mine radiolarian chert blocks from vertical limestone layers. In some cases radiolarites appear across large areas on the top of the Mogyorósdomb (Bácskay 1995b: 385–396).

A prehistoric mine was discovered in 1958 and the first archaeological excavation was made by László Vértes in 1960 and 1961. Vértes characterized this early mining activity and placed it within the timeframe of European mines (Vértes 1964): radiocarbon dating put it in the Copper Age (4520 ± 160 BP, Damon and Long 1964: 212–213). Geological exploration was carried out in 1963 and 1976, and from 1976 to 1986 archaeological excavations were continued parallel to the geological investigations (Bácskay and Vörös 1980: 7–8).

More than 500 pieces of different worked/used deer antlers and 800 pieces of quartz pebbles were excavated, nearly all with use-wear traces. Evidence of mining tools included wedge expanders, chisels, and hammers (Bácskay and Vörös 1980: 30–41; Vörös 2007: 28–29). The mining process was generally the same as elsewhere in Europe: upper soil was first removed, following which exploitation of the raw material began immediately in smaller galleries. The size of these pits varied. In some cases, mostly in the case of high quality raw material, radiolarian chert layers were traced to a depth of more than 7 m (Bácskay 1995b: 386).

Newly collected chert material

Nowadays chert outcrops are still easily found in the area. This situation can be documented across nearly the entire hilltop. Radiolarian chert layers stand vertical. The tectonic drifts moved the layers into an upright position, making it easy for the prehistoric miners to find and mine them. Wherever tectonic movements had not altered the situation, layers stayed so deep under the surface that erosion could

not reveal the chert deposits. The greyish chert blocks which reached the surface are very easy to dig out from the limestone.

CHERT FROM BAKONYCSERNYE–TÜZKÖVESÁROK

Radiolarian chert platforms of good quality and good for knapping can be found in the Jurassic limestone formation on the Bath level. Most of them are red in colour with blackish manganese impurities. The first geological survey by Lajos Kocsis in 1967 uncovered some mining pits and mining tools on the western slope of a deep valley called Tüzkövesárok. The average depth of the pits was between 1 m and 2.5 m. Angularly positioned radiolarite layers appeared at a depth of approximately 1.5 m (Bácskay 1982: 10). The mining tools were made of deer antlers which is typical of the Neolithic (Bácskay 1995c: 401).

New data from newly collected chert material

The Lithotheca Collection records only three samples from this area. Their surface is shiny, homogenous and slightly waxy. The colours vary between red and yellowish red, while the third piece (L86/104) is greyish in colour.

The new survey was concentrated in two main areas: the already well known valley of Tüzkövesárok and the valley in the southern part called Hosszú-Kígyós.

Bakonycsernye-Tüzkövesárok

A great deal of eroded chert deposits/layers and fragmented radiolarite flakes can be found in the southern part of the settlement, between the valley of Tüzkövesárok and the place called Erdei Szentély. The layer with radiolarian cherts can be followed easily through the valley. The chert comes mostly as block formations, but also as nodules in some cases. The colour varies from shiny light red, sometimes with light veins (so-called Szentgál-type), to brick-red and dark brown, yellow and mustard yellow. Reddish pieces with yellowish stripes and a less shiny surface have been documented, too.

Bakonycsernye-Hosszú-Kígyós

Chert blocks and nodules can be found sporadically on the eroded surface in the ridding-cut of the Hosszú-Kígyós, dented into the eastern slope of the hill called Hárshegy. The colour of radiolarite pieces alternates mostly between red and dark brown. The larger flint nodules of greyish colour, whitish cortex and homogenous surfaces can be classified as Tevel-type flints. Some sponge remains that can be seen in their matrix under the microscope connect them with the deep-sea formatted flints

originating probably from the Cretaceous age. Only these so-called Tevel-type flints from the vicinity of Pápa were known as local flints until now, this beside the imported flints from Moravia (Biró 2011: 213). It can be assumed that different types of flint nodules can be found in this wider area.

CHERT FROM BAKONYBÉL

This area was never explored for chert resources and there is no archaeological data from the vicinity of Bakonybél. Two bigger geological territories had previously been examined: the so-called Tűzkőhegy and the deep and long valley of the Száraz-Gerence.

Bakonybél-Tűzkőhegy

Eroded flint blocks are present on the surface to the north of the traditional Jurassic formations in the northern and western slopes of the Tűzkőhegy mountain. The so-called Liassic flints can be found in different hues of red, brown and yellow. The use of this raw material is evidenced in the archaeological material from different excavations in the vicinity Pápateszér – Állomás dűlő (Regenye and Biró 2012: 10) and Veszprém – Jutas (Regenye and Biró 2014: 34). A larger dark brown radiolarite nodule was found on the lower terrace of the hill, but its provenience is still questioned, as it could be in secondary position.

Száraz-Gerence

The deep valley of Száraz-Gerence is located in the north of Bakonybél, between the hill of Kőris-hegy and Som-hegy. Many radiolarite pebbles and radiolarian chert flakes can be found in the river wall (Fig. 5). The collected pieces vary widely in colour and type. Colours are between red and brown with white veins, but some yellow pieces with homogenous internal structure have also been documented. The shiny red pieces are very similar to the so-called Szentgál-type radiolarites.

CRF-examination results

A CRF X-ray analytical field instrument was chosen to prove the variation in radiolarian chert from the Bakony Mountain. The set is an analogue X-ray tube which bombs the surface with high intensity beams with the help of an optimized drift detector. The length of the reflected waves shows the presence and the quantity of the different elements (Table 1). The range of the impacts gives the rate between the elements².

² I am grateful to Zoltán Zentai for the CRF-examinations.



Fig. 5. Radiolarite pebbles in Száraz-Gerence. Photo by the author

Several elements were detected in the different samples: sulphur, potassium, calcium, scandium, titan, vanadium, chromium, manganese, iron, cobalt, nickel, copper, zinc, arsenic, selenium, rubidium, strontium, zirconium, molybdenum, tungsten, mercury, lead, silver, cadmium, tin, antimony, tellurium, caesium and barium. Five of these elements in quantities comparable with statistical methods were detected in every sample: potassium, calcium, titan, manganese and iron. In the case of the other elements, the margin of error of beam impacts was too high in the different samples or it was impossible to detect the amount of certain elements in the samples under examination.

The divergence between groups of samples from different geological sites in terms of potassium, calcium, titan and manganese was statistically significant. Taking into account the average ratio percentages of these elements in the samples, ANOVA showed that only the Fe ratio is similar in each sample, while the ratio of other elements differs significantly (Fig. 6). The control sample from Wien-Mauer does not differ in the ratios from the Transdanubian samples.

A comparative check of different element ratios in the raw material samples demonstrates a significant separation of the manganese ratio in the samples from Szentgál-Tűzköves compared to potassium, calcium and titan (Fig. 7). Thus, it would appear that radiolarites can be differentiated by analyzing the ratio of different elements. However, if we compare this to the results of the hierarchical cluster analysis with Ward linkage, only six bigger groups can be drawn (Fig. 8). The groups are very heterogeneous in terms of sample location. For instance, the Bakonycsérnye samples were sorted with samples originating 50 km away. In some cases, the closest geological sources showed the greatest differences, although the samples were taken 100 m apart and their

Table 1. CRF-examination raw data (number of impacts of potassium, calcium, titanium, manganese and iron)

Total number of impacts	Number of impacts						Sample No.	Geological source
	K	Ca	Ti	Mn	Fe			
5391.62	35.86361798	49.12290	0	0	14.97491	1	Hárskút-Rendkő	
4771.70	39.60789656	23.41409	2.081229	1.091644	20.77645	2	Hárskút-Rendkő	
4880.95	33.06774296	16.81333	5.776744	2.093855	36.94936	3	Hárskút-Rendkő	
4133.99	38.97832361	24.91491	7.355122	1.674411	24.8779	4	Hárskút-Gyenespuszta	
3765.06	30.25927874	15.12300	2.517623	2.194387	47.74452	5	Nagytevel	
2939.14	24.20878216	28.43008	4.250563	3.158407	33.80581	6	Bakonybél-SzárazGerence	
4792.97	25.01246617	36.15754	2.812452	2.934298	30.99456	7	Tüzkövesárók	
21656.79	7.723720828	13.59370	2.381285	56.38837	17.81474	8	Szentgál-Tüzköves	
56112.69	2.300691697	93.80358	0.305599	0.525300	2.403734	9	Hárskút-Borostyán-hegy	
6129.15	30.86822806	40.67807	3.243353	0	21.7221	10	Bakonybél-Tüzkő-hegy	
10287.79	14.99573767	72.81253	1.988279	0	8.551302	11	Bakonybél-Tüzkő-hegy	
13461.95	16.87548981	59.54917	2.160088	0.978536	16.75537	12	Wien-Mauter	
16690.80	10.21868335	62.85535	1.668384	4.490677	16.96186	13	Wien-Mauter	
1416.77	35.5270086	22.87527	6.058852	4.650720	24.09848	14	Bakonycsernye-Hosszúkigyós	
38135.47	1.77842308	96.27224	0.201309	0.367243	0.985408	15	Hárskút-Borostyán-hegy	

Total number of impacts	Number of impacts						Sample No.	Geological source
	K	Ca	Ti	Mn	Fe			
21024.09	17.17534504	22.23055	4.272194	37.86028	16.66507	16	Szentgál-Tűzköves	
6928.93	27.25500185	29.4044	4.027173	3.193278	34.14524	17	Bakonycsérnye-Tűzkövesárók	
20941.59	5.8639769	86.48856	0.779883	0.506074	5.900459	18	Bakonybél-SzárazGerence	
3662.09	35.35958974	21.56692	5.108831	2.607800	32.25917	19	Lólkút	
3237.19	36.4553826	33.67736	4.63339	0	22.34067	20	Nagytevel	
3445.21	19.39243181	49.93281	1.060603	4.463589	22.28572	21	Hárskút-Gyenespuszta	
3250.31	21.54809849	43.17619	1.005750	4.698321	24.70195	22	Hárskút-Rendkő	
4132.33	28.78981108	37.80361	4.102770	2.325565	21.9663	23	Hárskút-Rendkő	
113964.37	1.033902087	98.03161	0.132331	0	0.38054	24	Nagytevel	
2849.27	39.21846648	17.36059	4.642242	0	34.7503	25	Lólkút	
3234.23	26.25168896	23.76516	2.820764	3.365562	36.87555	26	Bakonybél-SzárazGerence	
6420.78	0	0	0	63.69475	36.30525	27	Bakonycsérnye-Tűzkövesárók	
12557.09	21.72278768	27.65139	4.07872	28.06383	15.24812	28	Szentgál-Tűzköves	
56952.21	1.394151342	96.49896	0.093903	0.360337	1.522294	29	Hárskút-Borostyán-hegy	
2400.05	46.89902294	22.54120	10.75019	0	16.20008	30	Bakonycsérnye-Hosszúkigyós	
6906.79	23.74518409	28.54553	4.074686	1.472174	37.50338	31	Wien-Mauer	
17301.73	8.483082328	84.09454	0.828761	0.420478	5.070938	32	Bakonybél-Tűzkő-hegy	

ANOVA						
		Sum of Squares	df	Mean Square	F	Sig.
k	Between Groups	3369,777	10	336,978	3,047	,015
	Within Groups	2322,468	21	110,594		
	Total	5692,245	31			
ca	Between Groups	15445,567	10	1544,557	3,336	,010
	Within Groups	9722,864	21	462,994		
	Total	25168,431	31			
ti	Between Groups	99,940	10	9,994	2,442	,041
	Within Groups	85,955	21	4,093		
	Total	185,895	31			
mn	Between Groups	4498,142	10	449,814	2,683	,029
	Within Groups	3352,926	20	167,646		
	Total	7851,068	30			
fe	Between Groups	2254,350	10	225,435	1,815	,120
	Within Groups	2608,939	21	124,235		
	Total	4863,289	31			

Fig. 6. Significant divergence between groups – ANOVA-analysis

formation was the same. Based on these examinations, it is plausible that the Bakony radiolarites cannot be divided into subgroups by the ratio of the elements examined here and should be defined as a single unified group as was the case for the cherts from St. Veit (Brandl 2013: 102).

SUMMARY OF NEWLY DISCOVERED GEOLOGICAL REFERENCE POINTS

General conclusions

Extensive beds of Jurassic radiolarian cherts can be found embedded within Mesozoic limestone at various locations in the Transdanubian mountains. Beside known outcrops of radiolarite (Hárskút, Szentgál and Úrkút), radiolarite layers, fragments, blocks or nodules can be found in numerous locations along the Bakony mountain range (Fig. 9). Revised and new data on chert outcrops in the area enable a refined model of prehistoric chert supply in the region. Prior to this research and mostly because of the theory of the Szentgál-complex, the Szentgál area in the Late Neolithic Period, with the surrounding settlements of Lengyel Culture, was believed to be

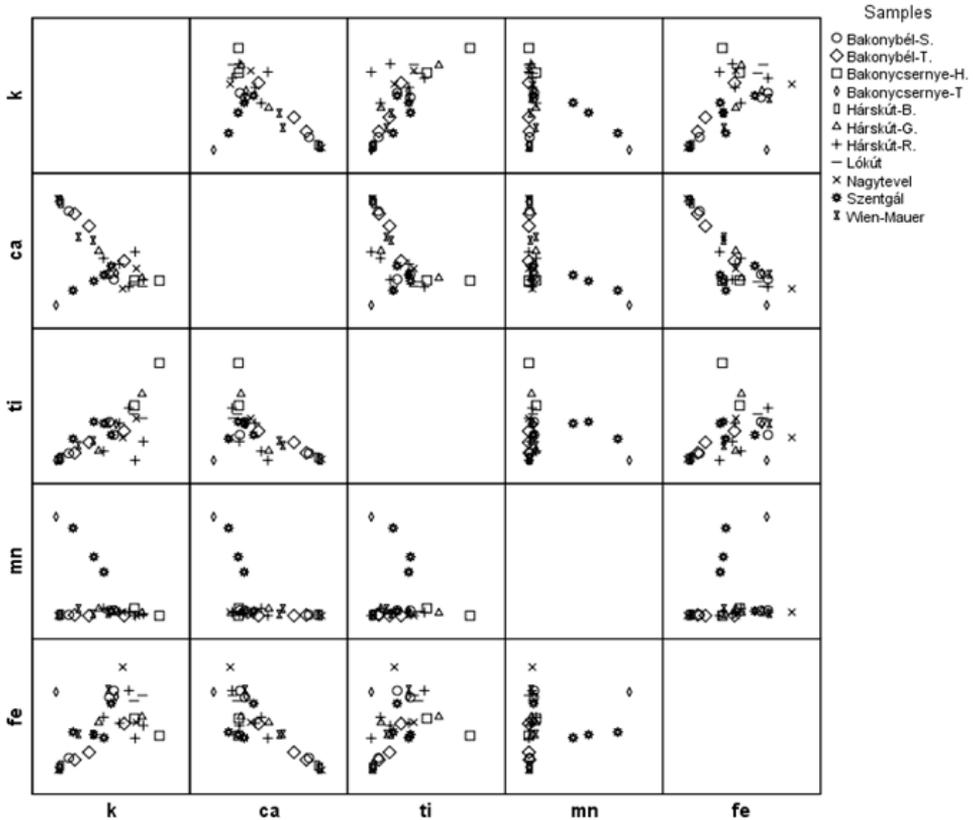


Fig. 7. Significant separation between the different raw material groups

a closed mining centre with specialised workshops. However, the new information reveals a more complex and multi-tier system:

- 1) Radiolarite of all colour variations, from brick-red to mustard yellow and deep brown, either with inclusions or a homogeneous surface without any insertions, is observed in nearly all areas from Bakonybél to Szentgál and the environs of Bakoncseryne or Sümeg.
- 2) All the radiolarian chert blocks, platforms or nodules can easily be located on the eroded surface and easily mined.
- 3) The raw material can be found across a huge area of the Bakony mountains as the radiolarian chert platforms are not impounded into micro-areas. Thick chert layers can be followed from Bakoncseryne up to the Zala Basin. The only difference is

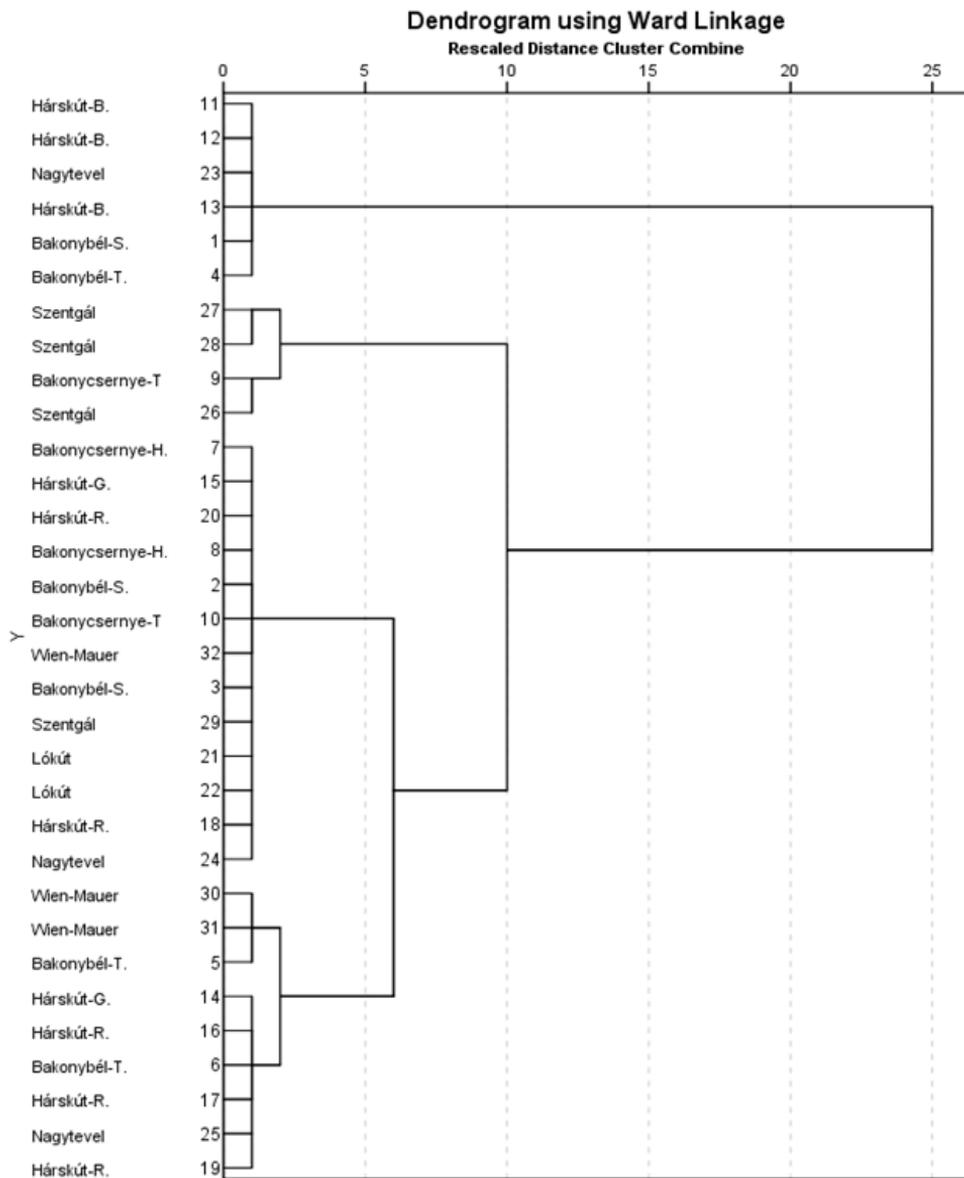


Fig. 8. Cluster analyses with Ward linkage between the different geological sites

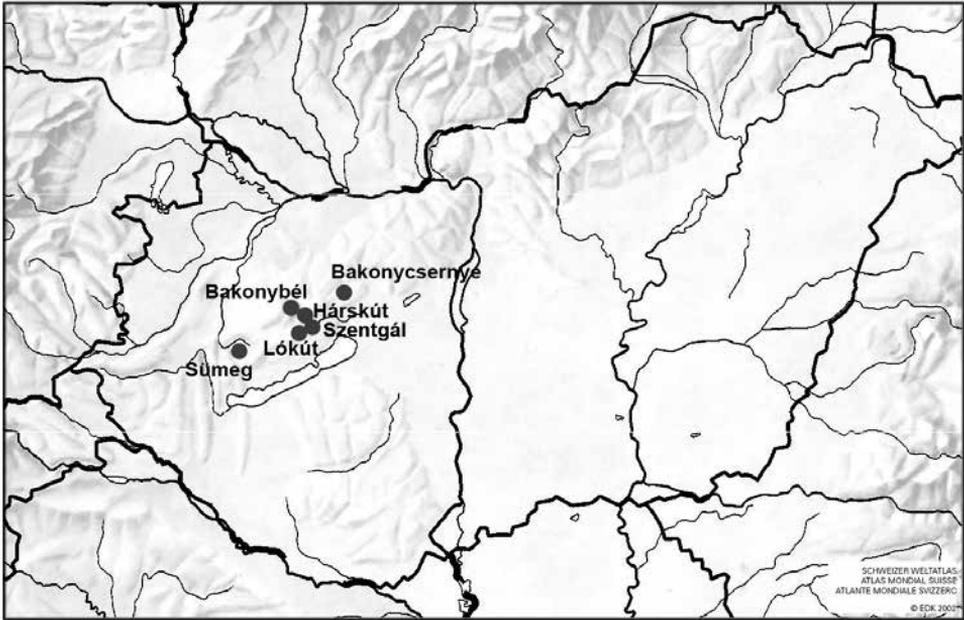


Fig. 9. Location of different Bakony radiolarites

that in the Bakony area chert deposits are localized close under the surface, while in the Zala basin blocks are 100 m deep below ground-level. Sümeg is the only exception, because tectonic movements rotated the limestone plates into vertical forms and erosion brought radiolarian chert deposits to the surface.

- 4) Cultural tradition sufficed to find these places on the eroded slopes or on the side of periodic streams. No deeper mining knowledge was required to dig out these radiolarite blocks.

Radiolarian cherts from the Bakony mountains cannot be defined or distinguished more specifically to location even with geochemical examination, primarily because all of Bakony is one formation and radiolarites layers were formed in the same period and under the same circumstances. The geochemical content of the radiolarites is very complex. In the Mesozoic period, chert platforms started to form everywhere at the same time in the Bath level under the Tethys Ocean. In deeper ocean basins, the conformation started already at the so-called Bajócián level. Thus it is that the formation of different radiolarian chert platforms started at the same level under the same circumstances. Radiolarites in this area have the same complex characteristics almost

everywhere (even if they are located more than 100 km apart). Colour variations are of no importance and the new results of examinations did not provide a geological location either. To conclude, the raw material deposits/outcrops were so famous in pre-historic times for no other reason than that they were easy to locate and easy to mine.

Revision of the Szentgál-komplex

In 2001, Katalin T. Biró and Judit Regenye established a new mining model for the Neolithic period centred on Szentgál. The connectivity models for this mining complex were different over time.

- 1) Expeditionary from mining centre to the various sites in the age of the Linear Band Pottery culture (LBP).
- 2) Not used in the times of the Sopot culture.
- 3) A defensive ring of a couple of smaller mining settlements (Szentgál-Füzikút, Szentgál-Teleki-dűlő, Szentgál-Tobán, Ajka-Pál major, Ajka-Fekete-hegy, Bánd, Herend-Csapberek and Városlőd-Újmajor) established around the mining centre in the Lengyel culture period (Biró and Regenye 2001: 95).

Once these theses are compared with the results of new technological examinations of samples from West Hungarian sites and the newly discovered geological resource areas in the Bakony region, a completely different picture emerges.

The expeditionary connection model for the LBP period is plausible. The only issue is how the raw material was transported to the settlements: by specialized groups or directly from the resource site to the place of application by the knapping group? As regards Sopot culture, the case is more than ambiguous. Szentgál-type radiolarites are missing completely from the lithic assemblages and the yellowish types dominate the chert material. Reddish Szentgál-types have been recorded among the chipped stones from Baláca (Biró *et al.* 1989: 57; Biró and Regenye 1991: 356), but other colour variations have been demonstrated to originate from Szentgál as well (or perhaps the red-coloured cherts were transported from other sites where the resource was available, like Hárskút and Lókút; after all, the red types can be found from Bakonycsérnye to Úrkút).

With regard to the Lengyel culture model, it is difficult to combine the newly discovered data with the existing model. Some groups may have shared the cultural traditions and mining locations in the Szentgál area, but it is more realistic to assume that chert was mined in a far larger area. Different communities could have used different raw material outcrops all over the Bakony Mountains at the same time. The lithic material from the settlements around the mine of Szentgál presents classical workshop material, just as Katalin T. Biró suggested in her publications (Biró 1993–94; Biró and Regenye 1991; Biró and Regenye 2001). But from a technological point of

view, the interpretation of these materials gives a different view. The flint debris is a classical waste assemblage from flint tool production, not the pre-processing of mined raw material. These settlements were not processing workshops connected to the mines, producing pre-cores for other settlements, but rather places of regular tool production like in every Neolithic village. For example, if we check the chert assemblages from the Szentgál–Füzikút site, we will see characteristic tool production waste: the cores are used to the very end, prepared from different orientations, truncated from different sides (mostly with *tablettes* or chopped from the cone-shaped end), etc. (Bíró 1993–1994: 101, Fig. 10/3, 6, 10). Even the small lamellas were chopped down from different orientations. This can be seen easily on the surface of the used-up cores as well. Beside these, a huge amount of debitage can be found: blades, lamellas and different truncated blades (in some cases, with signs of the percussion failures on the surface). Based on these technological facts, the defending ring around the mine and the pre-workshop activity in these settlements have no grounds in the evidence.

CONCLUSION

New evidence suggests it would be better to use the general name of Bakony radiolarites for the cherts from this area. The designations of smaller groups like Szentgál-type, Úrkút-Eplény-type, Hárskút-type, etc., which were identified mostly by their colours, should not be used anymore. All manner of colour variation can be found in each and every geological source and it is impossible to define them even by geochemical examinations. Radiolarite is a very common material, easy to find throughout the Bakony area and easy to mine, and therefore, precisely because of its commonness, it is pointless to try to pin it down to specific locations.

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